Measurement and Analysis of Geologically Induced Clutter

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LONG-TERM GOALS

The long-term goals of this effort are to:

- Improve the understanding of the physical mechanisms (below 5kHz) which scatter incident energy multi-statically into a receiver and which can possess target-like characteristics (clutter).
- Improve the understanding of the effects of seafloor geo-acoustic properties on clutter and reverberation.
- Improve the understanding of the effects of surface morphology and composition on scattering and clutter.
- Assess the suitability of current high fidelity reverberation and scattering models for model/data comparison.

OBJECTIVES

The objectives of this effort are to:

- Design measurements/experiments (including modeling support) to discriminate interface scattering from sub-bottom features and volume inhomogeneities in the ocean bottom in support of geologic clutter reduction studies (GCR).
- Design and acquire hardware and acquisition systems to participate in ocean experiments in support of planned GCR experiments.
- Improve the data processing and handling systems needed to analyze towed array data.
- Improve suitability of current reverberation models for performance prediction and model/data comparison.
- Provide a capability and validate schemes for automatically inverting *in situ* array reverberation data for relevant geo-acoustic parameters as well as bottom loss and scattering strength as functions of grazing angle.

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APPROACH

The first experiment has been designed and executed in support of the GCR effort at ONR. This was a large experimental effort conducted, after extensive planning near the New Jersey STRATAFORM area in the spring of 2001. This experiment involved researchers from MIT, SACLANTCEN, ARL-PSU and NUWC [1]. ONR's Mace Program Office contributed Bistatic source assets. Also, a second experimental effort under the Boundary Characterization Joint Research Program was conducted with SACLANTCEN, ARL-PSU, NRL, and DREA of Canada. That experiment focused on the statistical characterization of ocean boundary interactions but has several objectives in common with the GCR program. Boundary Characterization experiments were conducted in the springs of 2000 and 2001. Some of this data could be very helpful to the GCR effort since the STRATAFORM was the primary site of the 2001 experiment.

Data was taken over a wide a set of bistatic and monostatic geometries, ranges, frequencies, and pulse parameters to permit broad band analysis and also to test inversion schemes for important geo-acoustic and scattering parameters. Assessing the scattering characteristics of buried features like the meandering river channels identified by Goff, Austin and other ONR researchers [2] will be one of the highest priorities.

For the analysis phase, the issue of separating seafloor interface scattering from sub-bottom feature and volume scattering in the bottom will be studied. Recent work noted the importance of fine scale roughness characterization for the Bragg-like scattering component [3]. A study of surface morphology using the high resolution STRATAFORM bathymetry data will be made and compared with fractal (e.g., Goff Jordan) and composite roughness models (e.g. Jackson [4]) to assess merits and shortcomings of these approaches. Refinements to surface roughness models may be implemented where needed. Real 3-D effects for data taken on horizontal line arrays using directional sources have been incorporated into ray based models like GSM. Investigation into how best to incorporate these into higher fidelity codes is ongoing.

The manual inverse scheme used by Preston and Ellis for Rapid Environmental Assessment (REA) [5-7] involves a forward model and match approach using the Generic Sonar Model (GSM) [8] and *apriori* information when possible. This scheme has recently been automated to speed up the bottom parameter estimation process with a simulated annealing (SA) algorithm [9]. This permits near real-time higher quality performance predictions to be made. Minimum Least squared error norms have been developed and used to evaluate the results. Using the work of Hamilton [10], the PI has developed a constrained simulated annealing algorithm, which narrows the solution search space. The procedure includes incorporation of propagation loss engines like GSM and ORCA. The SA inversion methodology has been used on 2000 and 2001 broadband REA reverberation data taken by ARL/Penn State and SACLANTCEN [11,12]. The newer scattering strength models being developed by Jackson et. al., have just been incorporated into the automated inversion scheme. With the high quality of geo-acoustic ground truth available from the STRATAFORM area the data sets should be ideal for testing inverse schemes.

WORK COMPLETED

The PI helped plan and then participated in ONR's Geoclutter 2001 experiment (run by MIT's N. Makris) for reverberation in the STRATAFORM off New Jersey in the spring of 2001. Major updates to old pulse processing software were developed to run in near real time for beamformed and matched filtered output. Geoclutter reverberation data were analyzed at sea and initial results reported at the Geoclutter/Boundary Characterization workshop of Oct 2001 in Halifax [13].

Significant improvements were also made to the REA bottom parameter estimation methodology using the simulated annealing technique described above. The PI also helped plan and then participated in the Boundary Characterization 2001 experiments (run by SACLANTCEN's C. Holland) to measure bottom loss, local scattering, diffuse reverberation. pulse spreading and water-column volume scattering in the STRATAFORM. Using the new REA techniques, reverberation data were analyzed at sea and initial results are being reported at the Geoclutter/Boundary Characterization workshop of Oct 2001 in Halifax [12]. Techniques have been significantly improved for post experiment analysis that is ongoing.

The PI also is spending considerable effort in overseeing the building of a new ARL-PSU Five Octave Research Array (FORA) for ONR under a DURIP award. This new array will be used in the planned 2003 Geoclutter follow-on experiment.

RESULTS

Recent results from reverberation analysis on the 2001 experiments and the 2000 Boundary Characterization experiment are reported in [11-13]. As an example, Figure 1 below shows a polar display of matched filtered bistatic reverberation from the STRATAFORM site S1, on a towed array in a 50 Hz band centered at 420 Hz. Reverberation is color-coded vs intensity and time is mapped bistatically into location. Fig. 1 also contains the STRATAFORM bathymetry, (in black), sub-bottom horizons (in red) and small surficial features like iceberg scours. Buried river channels, the dendritic structures in black, are also shown (overlay provided by Goff [2]). The arrow indicates the towed array heading. Ambient noise (shipping) above the average background noise is seen as radials from the array in the plot. Since this is a single ping the data contain the array ambiguity i.e. there is a mirror image about array heading that is disorted in the bistatic displays. The source was an LFM 2s long from a vertical array of 7 elements.

IMPACT/APPLICATIONS

A better understanding of sonar clutter is key to improving sonar usability in shallow water. A wide area averaged bottom parameter SA estimation technique for REA such as the one being used here that utilizes directional reverberation measurements could provide a quick way to estimate sonar performance and optimize asset deployment.

TRANSITIONS

These same REA techniques are now being applied to select data from recent HEP experiments as part of ONR 6.2 efforts in support of the TAMBDA program at NAWC.

RELATED PROJECTS

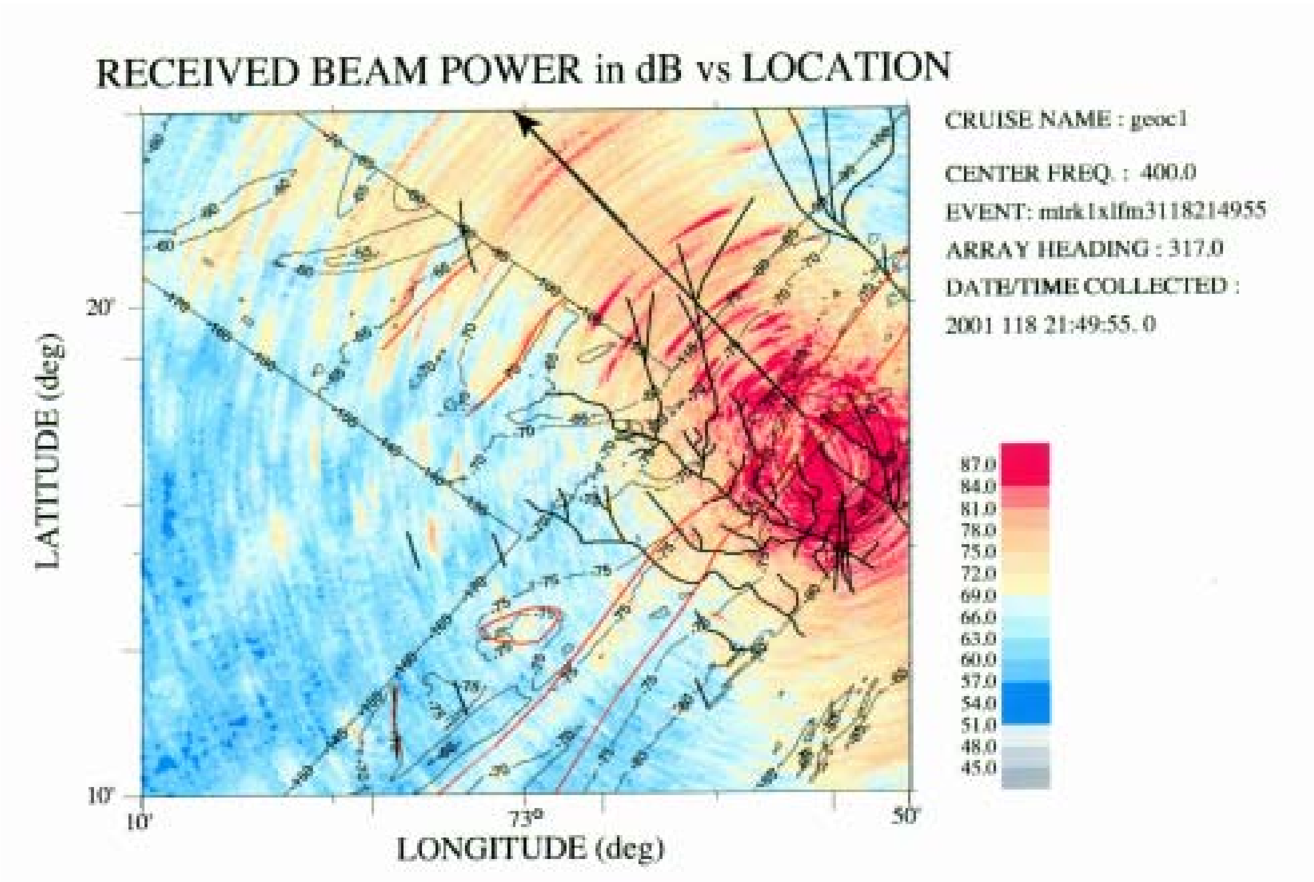

Fig. 1. Polar plot of the bistatic matched filtered reverberation on STRATAFORM from a 2s, 390–440 Hz LFM at Site S1. The black arrow direction indicates the array heading, the base of the arrow the array position, and the tip of the long thin triangle near the bottom of the ellipses shows the location of the bistatic source.

REFERENCES

[1] Geoclutter Cruise report: Draft copy, MIT, Aug 30,2001

[2] C. S. Duncan, J. A. Goff , J. A. Austin, C. S. Fulthorpe, “tracking the last sea-level cycle: seafloor morphology and shallow stratigraphy of the latest Quaternary New Jersey middle continental shelf”,Marine Geology 170(3-4),pp 395–421 2000.

[3] J. R. Preston, “Reverberation at the Mid-Atlantic Ridge during the1993 ARSRP experiment seen by R/V Alliance from 200-1400 Hz and some modeling inferences”, *J. Acoust. Soc. Am.* 107, 237-259 (2000).

[4] P. Mourad,, and D. Jackson, “A model/data comparison for low-frequency bottom backcatter,” *Journal of the Acoustical Society of America,* **94**, 344-358, 1993.

[5] D. D. Ellis, J. R. Preston, R. Hollett, and J. Sellschopp, “Analysis of towed array reverberation data from 160 to 4000 Hz during Rapid Response 97," SACLANTCEN SR-280, July 2000.

[6] J. R. Preston and D. D. Ellis, Summary of Bottom Reverberation Findings and Model/Data Comparisons during Three Rapid Environmental Assessment Trials, Paper 2aUWb3, Conference proceedings for 137th ASA meeting in Berlin Germany, March 1999 (Invited paper).

[7] Ellis, D. D., Preston, J. R., Extracting sea-bottom information from reverberation data, Paper 2aUWb11, Conference proceedings for 137th ASA meeting in Berlin Germany, March 1999.

[8] H. Weinberg, The Generic Sonar Model, Naval Underwater Systems Center, New London, CT, USA, Technical Document 5971D, June 1985.

[9] J. R. Preston, “Automated bottom parameter extraction from reverberation data with examples from LWAD and HEP data,” ARL TM 00-169, 25 October 2000.

[10] E. L. Hamilton, “Geoacoustic modeling of the seafloor,” *J. Acoust. Soc. of Am.*, **68**, 1313-1340, 1980.

[11] J. R. Preston, “Bottom Parameter Extraction from Long Range Reverberation Measurements,” Oceans 2001 Proceedings, Honolulu, Hawaii, November 2001.

[12] J. R. Preston, “Some shallow water reverberation highlights and bottom parameter extractions in the 325–825 Hz region from the Boundary Characterization experiment,” Geoclutter and Boundary Characterization Workshop Proceedings, Halifax, NS, Canada, October 2-3, 2001.

[13] J. R. Preston, “Some shallow water reverberation and bottom clutter observations near 400 Hz from the 2001 Geoclutter experiment,” Geoclutter and Boundary Characterization Workshop Proceedings, Halifax, NS, Canada, October 2-3, 2001.

PUBLICATIONS

J. R. Preston, “Bottom Parameter Extraction from Long Range Reverberation Measurements,” Oceans 2001 Proceedings, Honolulu, Hawaii, November 2001.

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Plus parts of many Geoclutter and Boundary Characterization planning documents are towed array design and test inputs.